Physical and chemical techniques to investigate the heaviest elements – Presence and future

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Early transactinide studies were much influenced by the assumption that isotopes of these elements decay predominantly by spontaneous-fission. As a consequence, rotating drums, wheels or tape systems were used to collect reaction products behind a target that were then transported in front of SF-detectors. Usually mica was applied for fission track counting. Also in the very first chemical investigation a frontal isothermal chromatography separation was coupled to a detection of SF-decaying nuclides by this technique. Clearly, these methods did not fulfil the stringent requirements of an unequivocal assignment of single-atoms to a given nuclide.

Later it turned out that not SF but α-decay is the dominant decay mode. Therefore, second generation experiments used event-by-event mode α detection systems, coupled to on-line physical separators in order to measure correlated decay chains. This approach immediately significantly reduced the random probability for an erroneous assignment of the decay of single atoms to a given nuclide.

Two physical separation techniques have been successfully applied in recent years: velocity filters (e.g. SHIP) and gas-filled magnetic separators (e.g. GNS). SHIP at GSI in Darmstadt was instrumental in the discovery experiments of the elements Bohrium through Darmstadtium, very likely also of the elements 111 and 112. Recently, experiments performed with the gas filled magnetic separator GNS at the FLNR in Dubna yielded evidence for the discovery of elements 113 through 116, possibly also of element 118. Both separation techniques are restricted to products from cold or "warm" fusion processes where evaporation residues have relatively high recoil energies. Current detection limits have reached the sub-pb level.

Chemistry studies of transactinides were much hampered by the technical challenge to couple fast and efficient on-line separations with high-resolution list-mode α-spectroscopy systems. In a first step, evaporation residues are collected in a thermalization chamber that are then continuously transported to a chemistry device. If the products are very volatile a pure gas (e.g. He) is used. For less volatile products solid aerosol particles (e.g. KCl) are added to the gas in order to serve as carrier particles for the adsorbed species (gas-jet technique).

So far, the following chemical techniques have been applied: for liquid phase investigations automated HPLC devices(e.g. ARCA) and continuous extraction systems (e.g. SISAK), and in the gas phase adsorption-chromatographic separators (e.g. OLGA). After chemical isolation, products are usually assayed for α or SF decay with conventional semiconductor detectors. In the SISAK device reaction products in an organic liquid are analysed in flow-through detector systems by liquid scintillation counting applying pulse-shape analysis. This method, however, is known to have a poor energy resolution. SISAK was therefore successful so far only if coupled to a physical separator (BGS at LBL). Promising are recent attempts to perform studies on chemically reactive surfaces (IVO/COLD for element 112 , CALLISTO for hassium). As yet, chemistry studies have been applied for transactinides up to hassium and very recently also for element 112. All these investigations are possible for nuclides with half-lives of a few seconds or longer.

Future success of transactinide research will much depend on, first, improvements in beam intensities (including duty cycles), second, novel target technologies, urgently needed to accumulate higher particles

doses in reasonable time, third, devices that are able to assign accurate mass numbers and/or atomic numbers to separated evaporation residues at a single atom level and, fourth, to next generation set-ups, able to perform physical and chemical studies with single atoms (ions) or molecules.

Several projects focus on these goals. Some examples are: at GSI a new high-intensity heavy ion superconducting CW-LINAC is evaluated and new chemical compounds are tested as future targets instead of metallic targets. At FLNR an on-line high-resolution mass separator (MASHA) is being built. At GSI the SHIPTRAP project focuses on the development of ion traps behind the velocity filter for detailed studies on single ions. PSI effort is currently devoted to the development of an ISOL target device that might be coupled to a physical separator (e.g. BGS). Such a system would enable novel investigations (e.g. of organo-metallic compounds).